WP 7 D7.5

D7.5: Social cost and benefits analysis for marine restoration and the policy relevance: case studies from Europe

Marine Ecosystem Restoration in Changing European Seas MERCES

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Executive Summary

Most marine ecosystem restoration projects are still at an experiment stage. A social cost and benefit analysis (SCBA) would provide useful information for decision making to support scaling up the restoration projects and assist in deciding which projects should be prioritised. This study first develops a framework for assessing the social costs and benefits for marine ecosystem restoration, considering the uncertainties associated with the restoration success as well as the factors that may affect cost and benefits of restoration. Three case studies are demonstrated: the deep-sea ecosystem restoration in the Dohrn Canyon in the Mediterranean Sea, an oyster reef restoration in Galway Bay, Ireland, and a kelp forest restoration project along the coast of northern Norway. The non-market value of ecosystem service benefits are used as welfare indicator of restoration projects in all three cases. All three cases show the large positive net present value (NPV) or expected net present value (ENPV). In the case of Dohrn Canyon, uncertainties associated with restoration success are shown to significantly affect the probability distribution of ENPV. Norwegian kelp forest restoration shows the restoration strategy in each period will depend on the state of kelp recovery.

The results show that data gaps and uncertainties, whether in terms of our understanding of ecological functions and processes, or our understanding of ecosystem services and their values, should not be ignored. In many cases, especially in the deep sea, the data gaps can be large. This does not in itself mean that SCBA cannot be applied, but it does imply that the "bottom line figure" is unlikely to be reliable or robust in itself. Rather, the process of carrying out a SCBA provides a useful framework for setting out the information that we do have, and assessing its reliability, alongside the gaps, and the potential for filling them. Often, the process of sensitivity analysis can help to understand how important certain gaps may be, and whether or not they could be material to the decision process. It can be possible, as seen in the oyster restoration example presented here, to demonstrate that changes to a subset of ecosystem services are in themselves sufficient to demonstrate a positive NPV and to justify an investment in restoration, and in that case the missing evidence on wider improvements is not material to the decision.

Through a survey carried out in collaboration with the MERCES Business Club, the study found short term and fragmented financing are the main barrier for long term and large scale marine ecosystem restoration. Innovative funding mechanisms such as public-private partnership, crowd funding and involvement of large financing institutions are needed.

Communicating information on the social costs and benefits of marine restoration are important for public support for restoration activities. Scientific results from restoration efforts also need to be better communicated to the public. Developing the political will and delivering the finances to up-scale marine restoration efforts and more broadly to achieve the goals of the European Biodiversity Strategy 2030 will require strong evidence to build business cases, leverage financing, overcome resistance in communities more focused on the social and economic objectives, and ultimately to achieve the long-sought mainstreaming of biodiversity and environmental concerns across all policy sectors. Ecosystem service valuation, appraisal, natural capital accounting and social cost benefit analysis are important tools that can provide such evidence to policy makers.

1. Introduction

Restoring degraded ecosystems is currently embedded in many important global and EU environmental and climate policies. UN has launched a new initiative entitled the "Decade on Ecosystem Restoration (2021-2030)" that aims to halt further degradation and to accelerate existing restoration efforts for land, aquatic and marine ecosystems. The need for restoration has also been stressed in several pieces of EU marine environmental legislation such as the Marine Strategy Framework Directive, the Birds and Habitats Directive, the Maritime Spatial Planning Directive, the Water Framework Directive, the Invasive Species Regulation and Bathing Water Quality Directive and the Common Fisheries Policy (Long 2019). The EU Biodiversity Strategy to 2020 (European Union, 2011) aimed for at least 15% of degraded ecosystems to be restored by 2020; however, it was already clear by the mid-term review, and more recently confirmed by the SOER2020 (EEA 2019) that "Europe is not on track to meet the 2020 target of maintaining and enhancing ecosystems and their services by establishing green infrastructure and restoring at least 15% of degraded ecosystems". Restoration of marine ecosystems is also highlighted in several multilateral and regional treaties such as the LOS Convention, the Convention on Biological Diversity, the OSPAR Convention, the HELCOM Convention and the Mediterranean Sea Barcelona Convention (Long 2019). Ecosystem restoration has demonstrated good conservation outcomes (Possingham et al 2015) and is regarded as an important management tool to reverse the degradation of many marine ecosystems (Mitsch 2014). Ecosystem restoration in the marine environment however is relatively new comparing to restoration in the terrestrial and freshwater environment (Ounanian et al. 2019). Studies on the topic have emerged in the last years (e.g. Bayraktarov et al. 2016, Ounanian et al. 2019. Duarte et al. 2020, van Tatenhove et al. 2020, Waltham et al. 2020, Blignaut & Aronson 2020).

Most recently, the EU has launched its Green Deal which includes the EU Biodiversity Strategy to 2030. Central to this is the development of a new "EU Nature Restoration Plan" with which "Europe will lead the way". This will include, subject to impact assessment, a proposal for legally binding EU nature restoration targets in 2021 to restore degraded ecosystems, in particular those with the most potential to capture and store carbon and to prevent and reduce the impact of natural disasters. In addition, Member States will be encouraged to ensure no deterioration in conservation trends and status of all protected habitats and species by 2030, with at least 30% of species and habitats not currently in favorable status moving to that category or showing a strong positive trend. These proposals have been developed in the context of "significant implementation and regulatory gaps hinder progress", as discussed further in section 6 below. The introduction of legally binding targets, as well as planned work to further develop methods, criteria and standards to describe the essential features of biodiversity, its services, values, and sustainable uses, are attempts to address these implementation and regulatory gaps. Achieving the targets will require significant investments in conservation and restoration, including substantial efforts outside the protected area network. In this context, the development and application of valuation and appraisal methods to build business cases, overcome opposition, secure financing and generally demonstrate the cost-effectiveness and welfare-enhancing nature of restoration targets, plans and projects has a crucial role to play.

However, current studies on social costs and benefits analysis of ecosystem restoration are very limited. On the benefit side there are a few studies estimating the values of restoration by for example using stated preference methods (e.g. Park et al. 2013, Dissanayake and Ando 2014, Hynes et al. 2021, O'Connor et al. 2020) or market data (e.g. Jenkins et al. 2010, Vasquez et al. 2014). A few studies have focused on the value of marine ecosystem conservation (e.g. Norton and Hynes 2014, Aanesen et al. 2018). On the cost side, Bayraktarov et al (2016, 2019) provide literature reviews for the costs of marine and coastal restoration, focusing in particular on mangrove, coral reefs, oyster reefs and seagrasses. Blignaut & Aronson (2020) report on eight meta-analyses on ecological restoration and rehabilitation projects and average costs and benefit-cost rations. Very few studies connect the benefits with the restoration costs for active restoration activities. A number of related studies have carried out cost benefit analysis for the creation of marine protected areas, which may or may not involve some restoration activity usually of a passive nature but even in these cases more often than not they involve qualitative rather than quantitate analysis (Davis et al. 2019, Rees et al. 2013).

Cost benefit analysis is an important tool to support decision making common for appraising investments in various marine industries such as oil, gas, and offshore wind power. It is more common to carry out a social benefit cost analysis (SCBA) when the social consequences, such as the environmental effects of a project on a population, need to be taken into account in the CBA exercise (Bos et al. 1974). If the total increased value of the benefits exceeds the costs of restoration, then it can be considered that the restoration had net economic benefits to society (Pendleton et al. 2010). SCBAs have been carried out for example for multi-usage of the sea (Chen et al. 2014, Koundouri et al. 2017) and for deep-sea mining in the Pacific Ocean (e.g. Wakefield and Kelley 2016, EU 2016). However the data gaps relating to deep-sea ecosystems, services and values mean that these studies make some quite heroic assumptions that cast doubt on the robustness of conclusions. For example, Pacific Communities (2016) use a proxy for the cost of replacing/restoring deep-sea habitats (since that is not known) based on the cost of creating saltmarsh, but adjusted using an "equivalence" between saltmarsh and deep seabed estimated using the "productivity logic" of Peterson et al. (2007) giving a ratio of 1ha of saltmarsh 'equivalent' to 203ha of 'flat and undifferentiated' seabed. With a discount rate of 7% (arguably high) they estimate the number of "Discounted Service Acre Years" and how much saltmarsh would be require to offset that: hence for example in one case, 470,000 deep sea-mount DSAYs would be offset by 2,315 wetland DSAYs at a cost of $26 million. For comparison they consider benefits using the assumption that the biological control, habitat & nursery, and genetic resources services of deep-sea bed must be no higher than estimates for those of 'cloud forests', although the studies underpinning those values appear to include other woodlands. These assumptions are very difficult to justify and the 'bottom line' conclusion of the study cannot be considered robust. Nevertheless, the process of setting out the SCBA, clearly exposing the data gaps and assumptions made, does help to illustrate what information would be needed to refine the analysis, and enables sensitivity analysis looking at how the results are sensitive to different feasible scenarios and assumptions (see Tinch & van den Hove 2016 for further details). Prioritisation through social cost-benefit analysis of restoration projects could also assist decision makers to make informed decisions when the demand for ecosystem restoration is high and resource is scarce (Blignaut et al., 2014). Consideration of the wider economic impact of restoration activity through ecosystem service accounting is also starting to become a priority internationally (UN, 2014) and aims to identify the temporal and spatial changes in ecosystems' contribution to society (Chen et al., 2020). Accounting within the System of National Accounts framework, including the SEEA (System of Environmental Economic Accounting) and SEEA-EEA (Experimental Ecosystem Accounts) uses exchange values, which is different from welfare values. It is the welfare values that is appropriate for use in CBA or SCBA appraisals. The limited CBA or SCBA for marine ecosystem restoration is attributed partly to the fact that most of the restoration activities taking place are pilots and small scale projects, and partly to the uncertainty associated with the success rate of restoration projects. Although most of the marine restoration projects are still at their experiment stage, a SCBA analysis would provide useful information for decision making to support scaling up the restoration projects and what measures are sustainable. However, data gaps and uncertainties, whether in terms of our understanding of ecological functions and processes, or our understanding of ecosystem services and their values, should not be ignored, and a *fortiori* must not be 'filled' in inappropriate ways. In many cases, especially in the deep sea, the data gaps can be large. This does not in itself mean that SCBA cannot be applied, but it does imply that the "bottom line figure" is unlikely to be reliable or robust in itself. Rather, the process of carrying out a SCBA provides a useful framework for setting out the information that we do have, and assessing its reliability, alongside the gaps, and the potential for filling them. Often, the process of sensitivity analysis can help to understand how important certain gaps may be, and whether they could be material to the decision process. It can be possible, for example, to demonstrate that changes to a subset of ecosystem services are in themselves sufficient to justify an investment in restoration, and in that case the missing evidence on wider improvements is not material to the decision. For example, the UK Marine and Coastal

Access Bill Impact Assessment (Defra 2009) identifies 11 ecosystem service impacts and attempts to value seven of these. A separate stated preference (SP) survey is carried out for non-use values, but these are not treated as additional in order to avoid possible double counting. The study concludes that active conservation of the UK marine habitat has a positive net present value, estimating that establishment of a network of MCZs throughout UK waters has a positive BCR of between 6.7 and 38.9. Although this is an imprecise conclusion based on far from perfect evidence about benefits, the results are reasonably robust in the sense that sensitivity testing shows that even given the uncertainty in the estimates it is very unlikely that the BCR could be below 1. Furthermore, the fact that only some of the improvements have been valued, and that the substantial non-use value estimates have not been included, lend further support to the conclusion.

In this context, it should be stressed that when dealing with uncertainty and possible irreversibility, there are different implications for action that risks damaging the environment compared to action that seeks to redress existing damage. As stressed in the Late Lessons from Early Warnings report: "Keeping options open and following multiple paths means that a particular option can be terminated if it turns out to pose high risks." (EEA 2013 p. 673). When dealing, for example, with plans to commence deep-sea mining, the substantial uncertainties, data gaps, and risks of strongly negative outcomes should motivate a precautionary and adaptive approach that places emphasis on slow steps, learning by doing and recognising the possibility of surprise and the possible need to stop an operation if the impacts turn out to be higher than anticipated. The learning that can accompany this process – if appropriate investments are made in monitoring and research – can lead to reduced uncertainty and better ability to predict the impacts of future operations, perhaps leading to reduced need to precaution in future (see Figure 1). Including appraisal and ecosystem service measurement and monitoring from the very earliest phases is an essential component of this process, even if there are too many gaps for the appraisal to inform decisions in the short term.

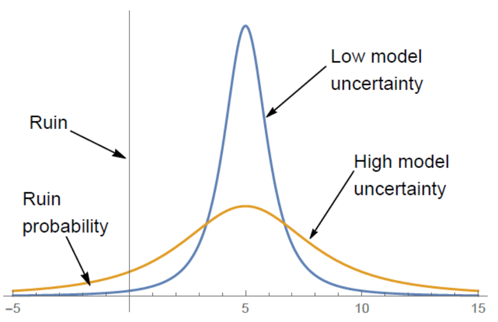


Figure 1 Comparison of different levels of uncertainty (source: Taleb et al 2014)

There are also substantial uncertainties regarding restoration, risks of failure, and great potential for learning by doing - but the downside is primarily loss of financial resources (in the case that restoration measures do not succeed), while in most cases there may be relatively little risk of causing further or irreversible environmental damage (although this is not always the case – for example risks associated with resuspension of pollutants in polluted sediments). Hence, by and large, the standard of proof for investments seeking to restore ecosystems or repair environmental damage should in many cases be lower than that for investments that risk damaging ecosystems.

2. Framework for social cost benefit analysis of marine restoration

The SCBA is a method aiming to ensure the most economic use of scarce resources in selecting investment projects or prioritizing policy measures (Bos et al. 1974). There are various guidelines on SCBA/CBA for both international entities such as European Commission (2015), at national level (e.g. UK HM Treasury 2018, New Zealand Treasury 2015, the Netherlands CPA/PBL 2013). The study follows the simplified procedures of the SCBA:

- Define the scenarios

Baseline scenario 0. It is important to clarify what the baseline scenario is. Baseline scenario for example can be defined as business as usual (BAU) with no restoration project. We have to aware that the baseline scenario can have different interpretations. In the case of UK coastal erosion for example, there are big differences between "do nothing", "do minimum (for example carrying on maintenance of infrastructure but make no improvements or additional investments) and "BAU" which mean the same as do minimum or something stronger depending on the circumstances.

Scenario 1-N: With restoration intervention for example using various techniques or sizes of restoring area.

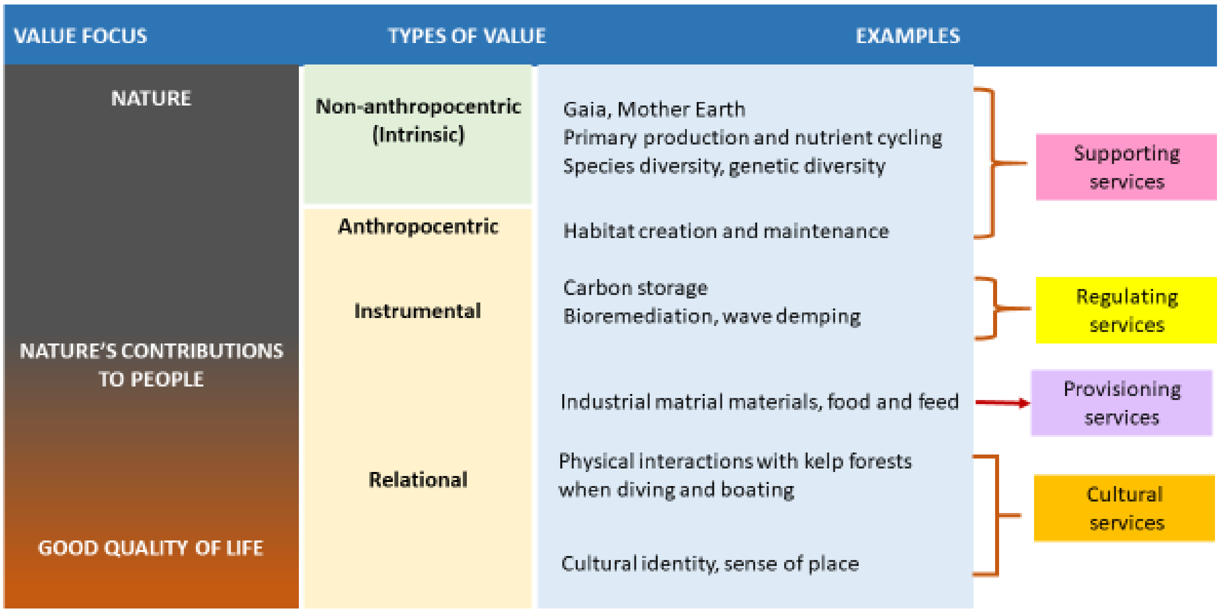
- Determine physical impacts, ecological impacts and affected population.

Several questions need to be addressed with experts and local stakeholders. That is, 1) how the restoration will improve the ecosystem? 2) what kind of ecosystem services will be affected? 3) How many populations will be affected? 4) who will be affected by the restoration activities?

- Identify the benefits and costs

Social benefits

Marine ecosystem restoration aims to improve the ecosystem hence the ecosystem function and the services it provides. The ecosystem services include provisioning services, cultural services, supporting services and regulating services. Figure 2 shows the ecosystem services provided by kelp forests in Norway.



Pascual et al. 2017, Gundersen et al.2016

Figure 2: Ecosystem services provided by kelp forest habitats (Chen et al. 2020)

Values for provisioning services such as commercial fisheries can be estimated by market values. While much of the cultural services, supporting services and regulating services do not have a market to trade the services. Non-market valuation methods therefore should be used to estimate the use or non-use values of the ecosystem services. Non-market valuation methods include for example contingent valuation (CV), choice experiment (CE) and travel cost method (TCM). In the report, CV is used to elicit the willingness to pay (WTP) benefits for a deep-sea ecosystem restoring project in the Dohrn Canyon (Mediterranean Sea) in Italy. TCM is used for an oyster bed restoration project in Galway Bay and CE is used for the kelp restoration in Norway.

Costs

The quantifiable costs include mainly the costs associated with restoration activities. The costs cover three phases of the restoration project: the preparation phase, the restoration phase and the monitoring phase post restoration. Both investment costs and operational costs are considered. The non-quantifiable social benefits and costs can be evaluated qualitatively.

- Tackling uncertainties

Uncertainty in restoration success

The outcome of marine and coastal restoration projects is typically quite uncertain. Markov models can be constructed to illustrate the transition of ecosystem /habitat status from one period to the next after restoration activities. Figure 3 illustrates an example of such a Markov model.

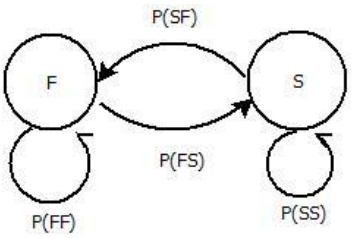


Figure 3 A Markov model for Restoration successful rate transition probabilities.

Uncertainty in costs and benefits

Monte Carlo (MC) simulation can be adopted to simulate the effects of uncertain costs and benefits on the net present value (NPV). This is a computer-based technique which draws statistical samples from given probability distribution of the uncertain costs and benefits. MC provides an assessment of the combined effects of multiple sources of uncertainties embedded in the cost and benefit variables.

- Calculating expected net present value (ENPV) or the cost-benefit ratio (CBR)

Assuming that uncertainties in i) restoration outcome and ii) costs/benefits are independent, the expected net present value (ENPV) can be calculated as

$$ENPV_T = \sum_{t=1}^{T} \beta^t (B_t \times p_{FS_t} - C_t) \tag{1}$$

where β is the social discount factor. B_t is the expected ecosystem benefit. C_t is the expected restoration costs and p_{FS_t} is the probability of successful restoration during period *t* following the Markov model in Figure 3.

When probability distribution of NPV has thick tails, ENPV might not be a good decision criterion. Additional information needs to be provided. For example, the probability distribution should be plotted. And if there is a low probability but catastrophic outcomes, for example anything to do with critical natural capital, then a more robust/precautionary approach may be preferable. In addition, if the cumulative risks or impacts are not taken into account and/or if the uncertainties in the CBAs are not independent, ENPV will be biased (Hoehn and Randall 1989).

The choice of discount rate is hard to justify objectively (Arrow et al., 2012) but has great influence over results (Weitzman, 2007). While some argue that discounting is inappropriate for long-term, significant environmental changes, not using discounting leads to substantial problems. Possible compromises include declining or hyperbolic discount rates, or low constant rates (see e.g. Kirby, 1997). Heal and Millner (2014) argue that there are no objectively correct discount rates, just different ethical positions that need to be weighted, an “exercise in social choice” that requires aggregating “the diverse preferences of individuals into a representative discount rate”. In practice, national governments and international institutions typically have a standard rate to ensure consistent discounting across all public sector appraisals (European Commission, 2015) and these sometimes take account of long-term issues in innovative ways: the UK for example uses rates that decline over time, and uses lower rates for health impacts (HMT, 2018). In all cases, CBA should consider the impact of the discount rate on the analysis, including sensitivity analysis using different discount rates and explicit discussion of impacts in different time periods.

3. Case studies for marine ecosystem restorations

Three case studies from MERCES projects are used as examples in illustrating how social costs and benefits analysis could be carried out for marine restoration projects. The three cases are the ecosystem restoration in the Dohrn Canyon in the Gulf of Naples in Italy, oyster reef restoration in Galway Bay, Ireland, and the kelp forest restoration in the Northern Norway.

3.1. Deep-sea ecosystem restoration: Dohrn Canyon in the Mediterranean Sea [1]

The Dohrn Canyon is the main canyon crossing the Gulf of Naples. The Canyon is up to 1000 meters in depth in places and follows two main branches, the eastern one and the western one, merging in a single branch in a NE-SW direction. The Dohrn Canyon is ~12 nautical miles off the Naples metropolitan area that is among the most densely populated Italian cities. Along the gulf’s 195km of coast approximately 30 ports and more than 300 maritime constructions are located. In recent decades a number of unique species have been discovered in this canyon, e.g.

[1] The description of the Dohrn canyon case study is taken from the MERCES paper that uses a choice experiment to analyse the ecosystem service benefit values from the restored canyon (O’Connor et al. 2020).

coexistence of cold-water corals (*Madrepora oculata*, *Lophelia pertusa (Desmophyllum pertusum)*, and *Desmophyllum dianthus*) and the large size bivalves (*Acesta excavate*, *Neopycnodonte zibrowii*). Over many decades this canyon has been subjected to high intensity human uses linked to coastal zone pressures. This has resulted in degradation of the environmental conditions of the canyon and the presence of litter along the canyon axis and walls. The anthropogenic (human related) activities influence the biodiversity of benthic fauna associated to the canyon system with different impacts when different benthic groups (from micro to megafauna) are considered. Figure 4 illustrates the location of the Dohrn Canyon in the Central Mediterranean Sea.

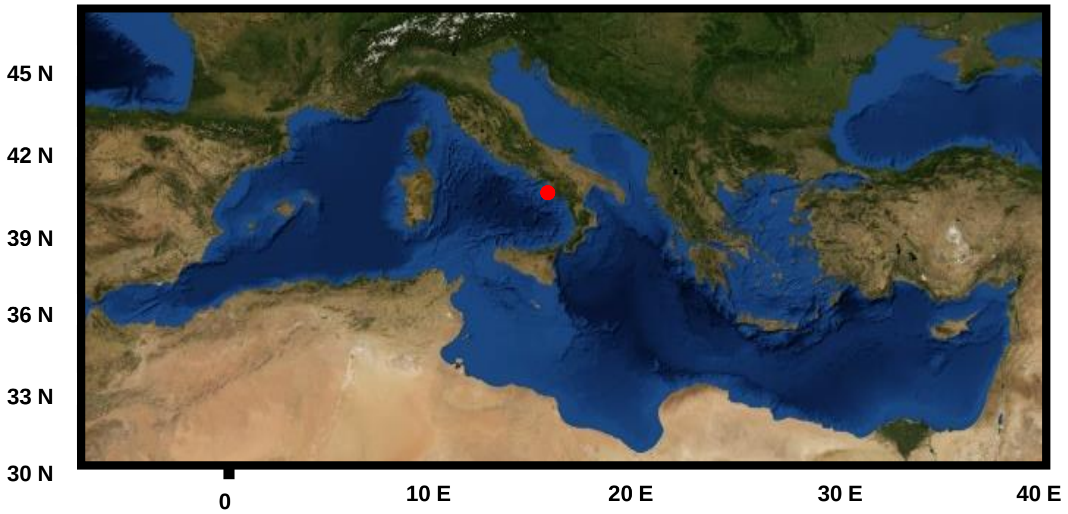


Figure 4 The Dohrn Canyon in the Central Mediterranean Sea

In order to restore the canyon ecosystem it is intended to deploy a number of “ARMS” (Autonomous Reef Monitoring Structures) in the main axis of the canyon at an approximate depth of 200 m. Artificial Structures for Deep-sea species recruitment and Ecosystem Restoration (ASDER) provides support for “ARMS” (Autonomous Reef Monitoring Structure) in the main axis of the canyon. ARMS have been previously used to monitor coastal marine biodiversity across regions (https://www.oceanarms.org/). The special and multilayer structure of ARMS allow for the colonization of a wide variety of organisms as they meet different demands in terms of environmental conditions and protect organisms against grazing. Moreover, the use of ARMS reduces the costs related to field work and monitoring for habitat restoration projects and their use does not depend on the natural substrate characteristics (Mirto & Danovaro, 2004; Danovaro et al., 2016; Pennesi & Danovaro 2017). Once the lander is colonized by organisms it can be transferred to degraded areas to promote recolonization of benthic organisms. The pilot project of restoration was managed by the Polytechnic University of Marche in collaboration with the

Stazione Zoologica Anton Dohrn in the framework of the MERCES project. Figure 5 shows ASDER provides support for three Autonomous Reef Monitoring Structure (“ARMS”).

Figure 5 ASDER that provides support for three Autonomous Reef Monitoring Structure (“ARMS”)

The restoration scenario is to create a marine protected area (MPA) of size ~2 hectares at depth 500-600m in the Dohrn Canyon. The restoration will require 50 landers with 3 ARMS units in each. The restoration scenario is compared against the business as usual, i.e. without the new MPA and the restoration activity.

Table 1 illustrates the annual ecosystem service benefits and total annual restoration costs for 50 landers. The ecosystem service benefits are evaluated by choice experiment method (O’Connor et al. 2020). The total annual restoration costs for 50 landers include preparation phase, restoration phase and post restoration monitoring. In the post restoration monitoring phase, monitoring happens only in year 7 and 10. The restoration activity is carried out in year 1. The restoration success rate indicates the probability of ecosystem recovering from a deteriorate state to an improved state each year after the initial restoration intervention. Annual ENPV and total ENPV are calculated following equation 1. Ecosystem service benefits are measured by willingness to pay by individuals and are elicited by an online public survey carried out in Italy using the contingent valuation (CV) method. The aggregated ecosystem service benefits are assumed to be collected from all tax payers in Italy i.e. via a nationwide taxation system. The expected net present value amounts to €4,099 million.

Table 1: Ecosystem service benefits, Restoration costs, Restoration success rate based on expert evaluation and ENPV: certain Restoration successful rate

Year	1	2	3	4	5	6	7	8	9	10
Ecosystem service benefits (B_t)(€ million)										
	-	-	-	2 105	2 105	2105	2105	2105	2105	2105
Total costs (C_t) (€ million)										
50 landers	0.104	0.208	0.298	0.069	0	0	0.069	0	0	0.069
Discount rate (β)	0.04									
Restoration success rate(P_{FSt})	-	-	-	0.45	0.34	0.36	0.36	0.36	0.36	0.35
50 landers										
Annual ENPV$_t$(€ million)	-0.100	-0.192	-0.264	799	590	588	578	532	523	490
ENPV (€ million)	4099									

In this SCBA we considered the uncertainties associated with benefits, costs, social discount factor, restoration success, and the associated (Markov) transition probabilities. We used Monte Carlo simulation to calculate the effects of these uncertainties on the ENPV. Figure 6 compares the probability density of NPV both with and without accounting for the uncertainty in transition probabilities. While the mean value (ENPV) is largely unaffected, the probability distribution of the NPV is significantly affected, showing much greater dispersion when we account for uncertainty in state transaction probability derived from expert opinion. Therefore, it is important to take into account uncertainty in the SCBA. In addition, the results have not considered the fact that value per ha may not scale up linearly and learning from the experiment are possible. Repeated restoration and planning based on learning from experience are included in 3.3 .

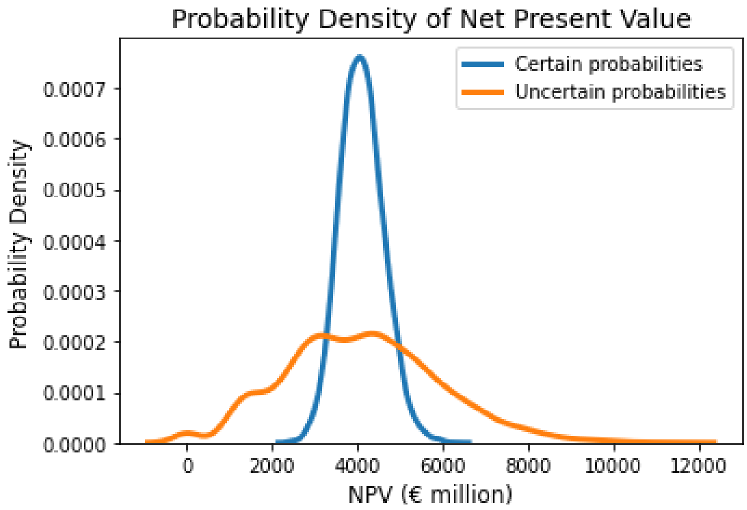


Figure 6: Probability density of expected net present value: certain versus uncertain transition probabilities. Ecosystem benefits, restoration costs and social discount factor are uncertain.

3.2. Oyster reef restoration: Galway Bay Ireland

The second SCBA involved examining the costs of the possible restoration of an oyster reef bar that would act as a protective barrier to a coastal trail that is repeatedly damaged by coastal storms. The benefits considered in this case related just to the recreational use value of the coastal path that will be lost if some mechanism is not put in place to prevent the complete destruction of the path.

This study was carried out at a coastal walking path located at Rinville West, Oranmore, on Galway Bay on the west coast of Ireland. It is a walking path along the very edge of the seashore and is adjacent to the Galway Bay Sailing Club, the Galway Bay Golf Resort and to the Rinville recreational forest park.

Figure 7 Rinville coastal walk

The coastal walking length (marked in red in Figure 7), with the starting point at the end of the narrow tarmac road and finishing in the last vegetated point connected to the coast is 1.07 km. While not on the usual tourist trail along the west coast of Ireland it is a popular section with local residents and in particular with dog walkers. A survey of users of the trail was carried out in 2018 to ascertain the pattern of trips taken. From a sample of 169 walkers it was estimated that the average number of trips taken per person per year was 65. The high average frequency of visits once again suggests that it is likely that it is local residents using the site rather than tourists.

Using the walker survey response data and a truncated negative binomial travel cost model it was estimated that the recreational use value of this coastal amenity was on average €11.24 per person per trip. This is the consumer surplus (CS) per trip and can be thought of as the access value to the site for the average walker. Given the actual average travel cost to the site per person per trip was €5.68 this would suggest an average willingness to pay (WTP) per person per trip of €16.92.

To calculate the aggregate use benefit value of the coastal walking trail for inclusion in the CBA we need to multiply the CS per trip by the aggregate annual number of trips taken to the site. The figure for expected annual trips comes from a people counter placed along the trail for the 12 months starting in December 2018. This suggests a minimum number of annual trips of approximately 41,000[2] and an annual WTP of €459,603. This represents the benefit value of the

[2] This is taken as a minimum number as the counter could not distinguish if a person passing by was walking beside another person so it is likely to be underestimating the total number of persons using the site. Also given this is a return journey trail the original count number double counts the trips taken so it was halved to get to this aggregate trip figure.

site to walkers on an annual basis and suggests that the loss of the site to local users could be substantial if the trail is lost due to storm surges and erosion.

Based on restoration costs estimates collected from the literature as part of the MERCES project (Deliverable D7.2) Table 2 presents the estimated costs of restoring an oyster reef bar along the length of the shore adjacent to the trail. The area would have had extensive oyster beds in the past but due in the main to overfishing only a sparse scattering of the native oyster (*Ostrea edulis*) can now be found in the bay.

Table 2 Renville Oyster reef materials and seeding cost assumptions

Feature	Value
Restored Oyster Reef Size (1070m by 6 meters)	0.642 hectares
Seeding rate per hectare	100,000
Cost of reef material (mixed Shell and stone) purchase and placement with mesh	€123,000
Cost of Seed	€1,155.6
Monitoring and Maintenance Costs per annum	€2500
Total Cost to establish in year 1	€126,656

The final step in the SCBA of the oyster reef restoration project was to estimate the NPV of the project over a 20 year time horizon. It is assumed that the reef is a protected site and no fishing for oysters occur. Assuming a social rate of time preference methodology, the standard test discount rate for application in economic appraisal of current and capital expenditure proposals recommended in the Irish Public Spending Code is 5%. Using this discount rate, the NPV of the use benefits from protecting the coastal trail over the 20 year time horizon is estimated to be €6,187,272 while the NPV of the costs of restoration are estimated to be €157,772. This suggests a highly positive NPV or a high net benefit cost ratio.

It should be kept in mind that this analysis only accounts for the use benefits derived through the protection of the shoreline walking trail. It does not account for the many other potential ecosystem service benefits from oyster reefs such as water filtration where excess nutrients from the water, particularly nitrogen, are removed; the service value of acting as a protected nursery ground for juvenile fish; while the 3-dimensional habitat created by native oysters is also known to support a higher level of biodiversity than the surrounding sediment/seabed. It could also be possible to maintain a sustainable annual harvest of oysters from the reef after a five year bedding in period. Even without the inclusion of these additional ecosystem service benefit values or the avoided protection costs for the golf course that is on the landward side of the trail the social benefit cost ratio is greater than unity.

3.3. Kelp forest restoration: coast of northern Norway

The third case involves the restoration of kelp forest in Northern Norway. Two major kelp species, *Laminaria Hyperborea* and *Saccharina Latissima*, are found along the Norwegian coast. Kelp forest habitats deteriorated along the Norwegian coasts since 1970s (Chen et al. 2020). Figure 8 shows the current distribution of the kelp forest in Norway. The map is adapted from Gundersen et al. (2017) and cited from Chen et al. (2020). The red line indicates the urchin barrens which dominate the Northern coast of Norway. Urchin barrens is a steady state in contrast to kelp forest and is caused by sea urchin overgrazing. In contrast to urchin barrens, the kelp forests provide rich ecosystem services (Gundersen et al. 2017, Krumhansl and Scheibling 2012). Figure 2 shows the various ecosystem services kelp forest could provide.

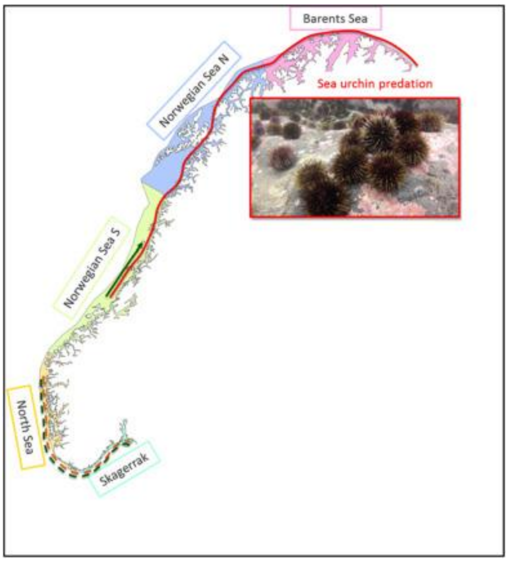


Figure 8 Kelp distribution along the Norwegian Coast.

Restoration of kelp forest in the Northern Norway is still at its experimental stage. Three restoration methods have been used. Kelp transplanting from donor site to the restoration site, removal of sea urchins (including harvesting sea urchins or using lime to kill the urchins), and using artificial reefs to restore the kelp population. Among the three restoration methods, liming is the cheapest costing €0.14/m^2 while artificial reefs are the most expensive method which cost €418.93 /m^2 (Groeneveld et al. 2019). Figure 9 shows a boat putting lime into the water in Hammerfest in Norway and an artificial reef covered by kelp forest.

Figure 9 Restoring kelp with liming (left) and artificial reefs (With kelp grown on the reef)(right).

The effectiveness and chance of success in using these methods will depend on the ecological state and properties of the area under restoration. In an urchin dominated area sea urchin density need to be limited for prospects of a long-term restoration success. Hammering the urchins is an effective technique but very time-consuming compared to liming. However, liming has shown very promising results in some areas and not in other areas. In areas with smooth bedrocks liming appear more successful than in areas with complex substrate types offering refuge for the sea urchins. Quicklime is also harmful to other species, echinoderms in particular. In sea urchin barrens there are little other fauna than urchins and at least our studies have not shown any significant negative biodiversity-effects from liming. Rather the opposite, the recovered kelp forests support a high biodiversity. Artificial reefs have shown success on short term but “our” reefs have been deployed in areas with high densities of sea urchins that eventually enter the reef structures and graze the kelp. Hence, if sea urchins are removed the effect will likely be better. Efforts for maintenance is another factor determine the success of kelp recovery. It is the same with kelp transplantation. Sea urchin density needs to be maintained low when a “natural” kelp forest develops. Combination of the restoration methods may be recommended.

Ecosystem benefits of kelp restoration are estimated in Hynes et al. (2021). The willingness to pay (WTP) for a full restoration with 40,000 m^2 amounted to €70.7 per capita. WTP for a medium restoration with 20,000 m^2 amounted to €59.1 per capita. These figures indicate willingness to pay for effective restoration of Norwegian kelp habitats in generally.

In order to implement large scale restoration project, not only NPV or ENPV for the restoration project is important for decision making, but the question about how much we should restore each period to achieve the highest social net benefits. Scaling up of restoration project needs adaptive and dynamic decision making and management in each period. In the case of Norwegian kelp restoration, removing urchins by lime in period 1 will obtain direct benefit of WTP for ecosystem services which will compensate the restoration costs. At the same time, removing the predator sea urchins will increase the kelp biomass in the period 2. Due to the uncertainty associated with urchin recruitment, the kelp forest may recover or may not. If the kelp forest is not recovered, urchins should be removed again in period 2. The same for period 3, 4, …, and time T. By using a bioeconomic model with the objective to maximize the social net benefits of restoration in each planning period, we identify the optimal urchin removal strategies in each period for 20 years. The regime shift between the two states, the kelp dominated state and the urchin barrens, are considered in the model. Figure 10 shows urchin harvest strategy will depend on the state of the kelp forest or how much kelp forest has been recovered relative to the urchin density. The lighter colour indicates the higher urchin harvesting rate. High urchin density and relative low kelp biomass will always need large amount of urchin removal to achieve kelp recovery. When urchin density decreases and kelp forest biomass increase, urchin harvesting rate will decrease. Figure 10 uses a fictional cost matching the scale of the benefit. The optimal harvesting strategy for liming is to harvest all urchin biomass in each period due to the low cost of liming.

Table 3 shows the net social benefits for full restoration scenario using liming and artificial reef as restoration methods. When using the liming method, NPV (with no uncertainty) for a 20 year horizon amounts to € 146,825 per m^2. When artificial reefs are deployed, the NPV (with no uncertainty) for a 20 year horizon amounts to € 140,407 per m^2. Due to the large uncertainty associated with benefits and costs estimate, the figure shows the social benefits from kelp restoration would be enough to justify the liming cost. The figure should be indicative rather than a precise measure.

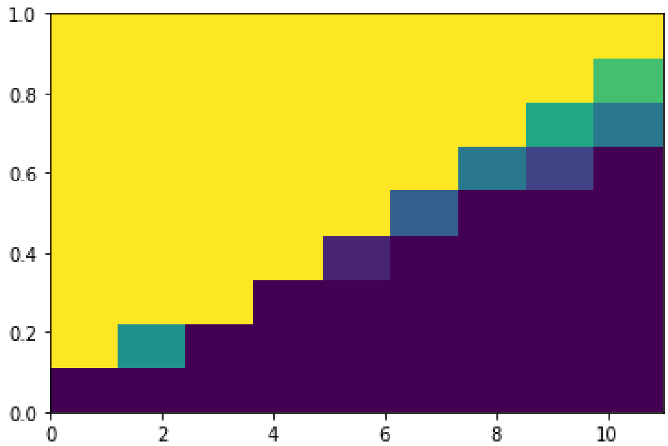


Figure 10 Optimal urchin harvesting strategy using a fictional cost matching the ecosystem Benefit. The lighter colour indicates the higher urchin harvesting rate.

Table 3 Optimal harvesting strategies and social net benefits for full restoration: liming and artificial reefs

Full restoration	Liming	Artificial reefs
	Per m^2	Per m^2
Optimal harvesting strategy in each period	100% of the total urchin biomass	
NPV for year 20s	€ 146,825	€ 140,407

4. Financial mechanism for marine restoration

A main challenge for restoration efforts is the high cost in contrast to fragmented and short term financing. Relying on public funding alone may not be sufficient to support marine restoration actions. Innovative new financial mechanisms to fund marine ecosystem restoration projects are needed, especially those aiming at mobilising private capital. With this in mind, a survey on "Financing for marine ecosystem restoration" was carried out under WP7 of MERCES in collaboration with the WP8 Business Club. The aim of the survey was to improve our understanding on how current financing mechanisms function for marine ecosystem restoration projects and what the private sectors' preferences towards marine restoration financing might be. The surveys were carried out via an on-line questionnaire between 11th December 2019 and 20th January 2020. Six responses on financing preferences were obtained from industry/NGO/Governmental/academia. Seven responses are obtained about financing mechanisms at project level.

Fragmented and short term funding are the main challenges facing most of the projects and those who involved in the marine restoration activities. The average length of the 7 restoration projects was 4.3 years. Public and government funding are the main source of funding. Multiple funding sources are common for each project. The respondents indicated that the selection of financing mechanism followed no clear rules or patterns and the mechanism is not connected to the outcomes of the projects. No project in the survey is funded by financial institution or institutional investors, i.e. in the form of loan, guarantee, insurance or equity investment. Emerging mechanisms which have been used in, for example soil remediation financing, do not seem to be used yet in marine restoration. Public-private partnership, crowdfunding, biodiversity offsets, nutrients or carbon trading are also still by and large absent.

On the side of private investors, it is important to understand their preferences and how to include their preference when designing the financial mechanism so as to facilitate their involvement either as sole investors or in the form of public-private partnership. Most of the respondents are expected to contribute to the projects via in-kind contribution and capacity building. Only three of the six would like to contribute financially more than five years. When facing funding gap, other business partners and NGOs are the most preferred collaborators. In addition to fragmented funding, there are several other barriers facing the private investors. For example, "Initial investment costs are too high", "The area requiring restoration are too large", "The timescales required to see ecosystem improvements are too long", and "It is difficult to cash out the return". There are several factors that hinder cashing out the returns from marine restoration investments. For example, "poorly defined property rights and free-riding" and "uncertainty of restoration success” are the two most frequently identified factors that hinder cashing out the returns. Long investment periods, lack of data and difficultly in moving from the status quo are also recognized as possible factors.

All respondents regard the projects as having “high environmental benefits” and “high social benefits” worth investing in. Preferred funding mechanism includes public-private partnership, revenue streams derived from the use of marine ecosystem and their services, and crowdfunding. When asked what kind of incentive measures they would like governments to introduce, they mentioned policy and relevant measures to facilitate industry-science collaboration, high levels of political commitment to encourage effective conservation and tax reduction.

5. Policy recommendations

5.1. Marine restoration strategies

During the UN “Decade of Ecosystem Restoration”, the main policy driver for restoration in Europe will be the EU Biodiversity Strategy 2030 (EUBS2030) and associated policy measures, with a key objective of the Strategy being to set up an EU Nature Restoration Plan. The strategy has been developed taking account of the failure to meet the original 2020 targets (i.e. maintaining and enhancing ecosystems and their services by establishing green infrastructure and restoring at least 15 % of degraded ecosystems), noting that “significant implementation and regulatory gaps hinder progress.” The European Environment – State and Outlook (SOER2020)[3] explains that although “Natura 2000 areas have a positive effect on ecosystem condition and biodiversity in surrounding areas, pressures remain high and the conservation measure undertaken are still insufficient”. Indeed, it has long been clear that biodiversity and restoration targets cannot be achieved solely through the protected area network, important though that is. The European Habitat Forum Assessment[4] notes on the positive side that the knowledge base has increased, but that ecosystem degradation continues. They identify these specific reasons:

- Baseline not clearly defined
- No commitment to specific restoration targets
- Lack of strategic planning
- Insufficient investment in restoration and green infrastructure

[3] The European environment – state and outlook’ (SOER) is published by the European Environment Agency (EEA) every five years. SOER 2020 is the 6th SOER published by the EEA since 1995.
[4] European Habitat Forum (nd), "The implementation of the EU 2020 Biodiversity Strategy and recommendations for the post 2020 Biodiversity Strategy" available from https://www.iucn.org/sites/dev/files/content/documents/eu_2020_biodiversity_strategy_and_recommendations_for_post_2020.pdf accessed 26/01/2021

The higher-level reasons behind these failures to maintain and enhance ecosystems and their services lie in well-known problems including weak implementation of existing legislation, failure to mainstream biodiversity and environmental concerns across all policy sectors, and insufficient resources for conservation coupled with failure to reform perverse subsidies. Behind that, the Forum identifies a lack of political will to take nature loss seriously, and the opposition of stakeholders with vested interests in the status quo. This reflects global and European pressures that have continued to marginalise environmental objectives in EU policy making, including the global and euro financial crises, failure to meet the Lisbon goals, migration and energy security concerns, rising populism, differentiated integration between member states (including Brexit) and the disconnect between the longer term environmental challenges and the short-term exigencies of electoral politics (Zito et al. 2019).

These problems are still present, and indeed the economic and social impacts of the current pandemic are likely to exacerbate them. And these are the problems that the EUBS2030 must solve if it is to meet the pressing need, identified in the latest "State of Nature in the EU" report (EEA 2020) "for a step-change in action if we are to have any serious chance of putting Europe's biodiversity on a path to recovery by 2030."

The EUBS2030 sits within the "European Green Deal", "Europe's new agenda for sustainable growth". Components of the Green Deal include, inter alia, the Green Deal Investment Plan, a Just Transition Mechanism, a proposed European Climate Law, a new Circular Economy Action Plan and the EU Biodiversity Strategy for 2030. The Green Deal frames the problems and solutions as follows: "Climate change and environmental degradation are an existential threat to Europe and the world. To overcome these challenges, Europe needs a new growth strategy that will transform the Union into a modern, resource-efficient and competitive economy." The tension between environmental and growth objectives remains clear in that framing, as is the disconnect between "climate" and "other environmental issues". The main focus of the Green Deal is climate neutrality by 2050, with decoupling of growth from resource use, and social justice ("no person and no place is left behind"). The EUBS2030 will have to work within that framework.

Thus, although the Mapping and Assessment of Ecosystems and their Services (MAES) EU Ecosystem Assessment 2020 claims that "Preserving and restoring ecosystems is central to the Green Deal", it goes on to explain that "Ecosystems are seen as solutions, not only to protect biodiversity but also to enhance carbon uptake and contribute to climate change mitigation a well as to deliver essential benefits to people, agriculture, and the economy." An example of how this translates to the policy sphere is given by the recent EU Parliament resolution on EU Forest

Strategy, which invites the Commission to "explore options to incentivise and remunerate climate, biodiversity and other ecosystem services appropriately" and "stresses the importance of developing and ensuring a market-based bio-economy in the EU". Ensuring sustainability within such frameworks requires strong evidence, and preferably monetary valuation, to recognise and internalise the importance of non-market services.

5.2. How can SCBA of marine ecosystem restoration inform and improve future marine restoration strategies?

- **SCBA is an important decision support tool in choosing effective marine ecosystem restoration activities and policies.**

The European Green Deal and the EU Biodiversity Strategy 2030 headline objectives place a strong emphasis on the importance of biodiversity for human wellbeing and development. The contribution of marine ecosystems to societal welfare is often however not properly accounted for as many of the transactions involved are non-market in nature. MERCES demonstrated the non-market ecosystem service values associated with a range of marine ecosystems and also how these values can be estimated for ecosystem service benefits associated with ecosystem types that are often not that familiar to citizens.

Under the Marine Strategy Framework Directive, Good Environmental Status threshold values should be set "on the basis of the precautionary principle, reflecting the potential risks to the marine environment." (Commission Decision (EU) 2017/848 of 17 May 2017). But beyond that, there remains a large margin for choices in strategy design, development of plans and targets, and decisions about policy instruments. There is a pressing need for integration of environmental values within a SCBA framework in policy processes to ensure that the most effective use is made of scarce conservation and restoration funds.

- **SCBA should be used for decision support in prioritising cost- effective marine ecosystem restoration activities and policies.**

SCBA, along with other economic impact assessment tools, can be used as decision support for marine ecosystem restoration activities and policy development, through assessing the consequences of environmental changes for human welfare.

In general, SCBA should be employed to help decision makers address the causes of ecosystem degradation by:

1) Clearly defining the baseline,
2) Specifying clear restoration targets
3) Comparing costs and benefits over long time periods to support strategic planning
4) Providing quantitative estimates of benefits and costs which is needed for both public and private investors for restoration investment.

By comparing the benefits from ecosystem services changes with the restoration costs under various restoration scenarios/policies, prioritization can be made among the alternative restoration activities and policy scenarios. As not all the impacts of ecosystem services on human welfare can be expressed in monetary terms, qualitative and non-monetary metrics indicating level of benefits should be used alongside the SCBA.

Monetary expressions of non-use values can be particularly contentious. However, it is important not to ignore these important values reflecting deep-held views on the desirability of protecting and restoring marine environments over and above any direct personal or economic benefits. Often, it may be possible to justify investments without including the non-use values, but these should nevertheless be discussed and presented as additional justification for action – as for example was done in the The Impact Assessment for the Marine Conservation Zone (MCZ) provisions in the UK Marine and Coastal Access Bill (Defra 2009)

Specific instances where SCBA should inform and improve forthcoming policy include:

The EU Nature Restoration Plan. This will include a proposal for legally binding EU nature restoration targets, and that proposal will be subject to Impact Assessment (IA). There will be resistance to legally binding targets from some Member States and from vested interests. The IA will have to demonstrate that the proposals are necessary, proportionate and beneficial. **Valuation of costs and benefits within a SCBA framework will be important for achieving this.** The new "action plan to conserve fisheries resources and protect marine ecosystems" and the national Member State maritime spatial plans are due in 2021. Again, **valuation evidence in a SCBA framework will be important for establishing and justifying targets.**

- **Catalogue and use multiple and non-market ecosystem service values for marine restoration**

The EUBS2030 highlights the need for "the quantitative measurement of ecosystems and their services and values, and their incorporation into accounting and reporting systems used by business and the public sector". There is a gap here when it comes to the measurement of marine ecosystem service values, but the gap is shrinking. MERCES and its sister projects such as ATLAS have contributed new knowledge and valuation evidence that should be used in future value transfer exercises for SCBA.

In particular, the EUBS2030 promises to report in 2021 on "methods, criteria and standards to describe the essential features of biodiversity, its services, values, and sustainable use". This will build on the first EU ecosystem assessment that lays the foundations for ecosystem service quantification and valuation at the European scale. At present, the experimental ocean ecosystem accounts mostly focus on carbon storage/sequestration, shoreline protection, fish nursery and habitat, and nutrient cycling. However, the growing evidence base will enable assessment of a broader range of impacts. This includes the potential to value whole system changes via stated preference methods, as successfully demonstrated in MERCES and ATLAS. This evidence demonstrates public WTP and non-use values that might otherwise be overlooked in a service-by-service assessment. These methods need to be covered in the Commission's work in this area.

There is a risk that the focus on natural capital accounting, and more generally on green/blue growth and market instruments, could create a focus on exchange values at the expense of welfare values required for other purposes such as policy appraisal. This would be a regressive step insofar as representing the actual values to people and improving environmental justice are concerned. The development of methods should advance in line with other initiatives, not only the SEEA-EEA revision which is focused on exchange values, but also processes including the IPBES Values Assessment, and the standards ISO14007 and ISO14008. Both ISO standards focus on welfare values, taking "an anthropocentric perspective" that "includes use and non-use values as reflected in the concept of total economic value when environmental costs and benefits are determined in monetary terms." **It is essential that the Commission's work on "Measuring and integrating the value of nature" (EUBS2030 Section 3.3.3) cover all monetary valuation methods and frameworks, including both exchange values for accounting and welfare values for SCBA.** MERCES demonstrated for example how restoring kelp forests and oyster reefs can provide significant ecosystem service benefit values and also be cost effective solutions to dampen down the effect of storm surges.

- **Use SCBA to inform integrated, cross sectoral and climate resilient marine and coastal planning**

Assessments often fail to achieve their full potential in terms of practical usefulness and policy relevance, in part through failure to balance “the trio of credibility, legitimacy and relevance”. We need now to go beyond the conclusions that people support restoration and having some monetary evidence of its value, to explaining how that fits in to the current policy framework. This application needs to go beyond project-level SCBA to include strategic level target setting, mainstreaming across the wider policy agenda (in terms of contribution to climate targets, blue growth and jobs), natural capital accounting at all scales (from continental level for monitoring, to local assessments for coastal industries and landowners), developing business cases and financing, and potentially Payments for Ecosystem Services (PES) or habitat banking.

In particular, under the Commission’s proposal for the first European Climate Law “Member States will also be required to develop and implement adaptation strategies to strengthen resilience and reduce vulnerability to the effects of climate change.” Marine/coastal restoration is an important component for the resilience/vulnerability aspect, and valuation will be important to develop these plans, build business cases, and access financing.

Although details of the new marine conservation policies remain to be determined, it is likely that financial instruments will be considered. For example, the recent EU Parliament resolution on EU Forest Strategy invites the Commission to “explore options to incentivise and remunerate climate, biodiversity and other ecosystem services appropriately” and “stresses the importance of developing and ensuring a market-based bio-economy in the EU, a clear indication of the general direction of policy thinking that is likely to influence new policy in the maritime space. **Any such financial instruments should be underpinned by strong valuation evidence to establish appropriate levels for fees and payments.**

- **Integrate valuation evidence in marine restoration financing**

The MERCES project identified the need for long term and integrated funding schemes to support marine restoration activities. Effective financing mechanism design in the future may need to connect to the outcomes of the restoration activities and the risks they face. More involvement from financial institutions and institutional investors is needed. Big European investment banks are now in the starting phase for planning the financing schemes for nature-based solutions, which is relevant for marine restoration as well. Innovative funding schemes such as public-private partnership, crowdfunding, biodiversity offsets, nutrients or carbon trading need to be tested. **SCBA should be an integral part of building the business case for financing.**

- **Raise awareness and public support for marine ecosystem restoration policy**

The EU Biodiversity Strategy for 2030 calls on Member States to integrate biodiversity and ecosystems into school, higher education curricula and professional training. The empirical examinations of attitudes toward marine restoration among the general public and marine stakeholders carried out in MERCES demonstrates that recognising the public's current level of knowledge with regard to marine ecosystems and restoration can assist in the development of educational tools and effective management policy that can influence behaviour that in turn may help reduce future damages to marine ecosystems. The results of the research suggest that public support could be increased through campaigns to increase awareness of marine restoration activity including highlighting major advances, success stories and expected benefits. **Part of this process should include communication on the values supported by healthy marine systems.**

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